

COCPIT: Collaborative Activity Planning Software for Mars Perseverance Rover

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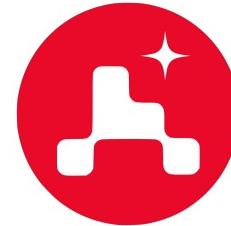
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Introduction



- Perseverance Rover landed on Mars February 2021
- Surface operations team members are distributed between North America and Europe
- COCPIIT is part of the Mars 2020 Ground Data Systems

COCPIT

Component-based Campaign Planning, Implementation and Tactical



Responsible for

- Activity planning
- Continuously verifying constraints
- Document Science Intent
- Model data and power resources
- APIs to interface with GDS tools
- Target association

Architecture

Collaborative web-application

Extends and customizes the
Playbook planning and execution
tool developed at NASA Ames
Research Center



Dev Stack

- Frontend
 - JavaScript, HTML, CSS, Backbone.js, d3, svg, Web Sockets
- Backend
 - Node.js, nginx
- Database
 - Redis for temporary storage
- Infrastructure
 - Docker, AWS, XML for permanent storage in S3, Single Sign-On Authentication Layer, Elastic Search

Planning Phases

COCPIT supports all planning phases

1. Parcel Development
 - Define and validate reusable Activities
2. Strategic Planning
 - Create plan fragment templates
 - Consider timing constraints
 - Assess heating requirements and resources
3. Campaign Implementation
 - Look-Ahead Plan for the next ~5 Sols
 - Includes communication passes
 - Ensure progression of science goals
 - Evaluate options, guide tactical planning
4. Tactical Uplink
 - Plan next sol(s) to be executed by the rover
 - Incorporate changes based on received data (i.e. status and latest images)
 - Ensure constraints are met
 - Generate sequences to send to rover
5. Tactical Downlink
 - View currently executing plan
 - Receive and analyze data

Navigator

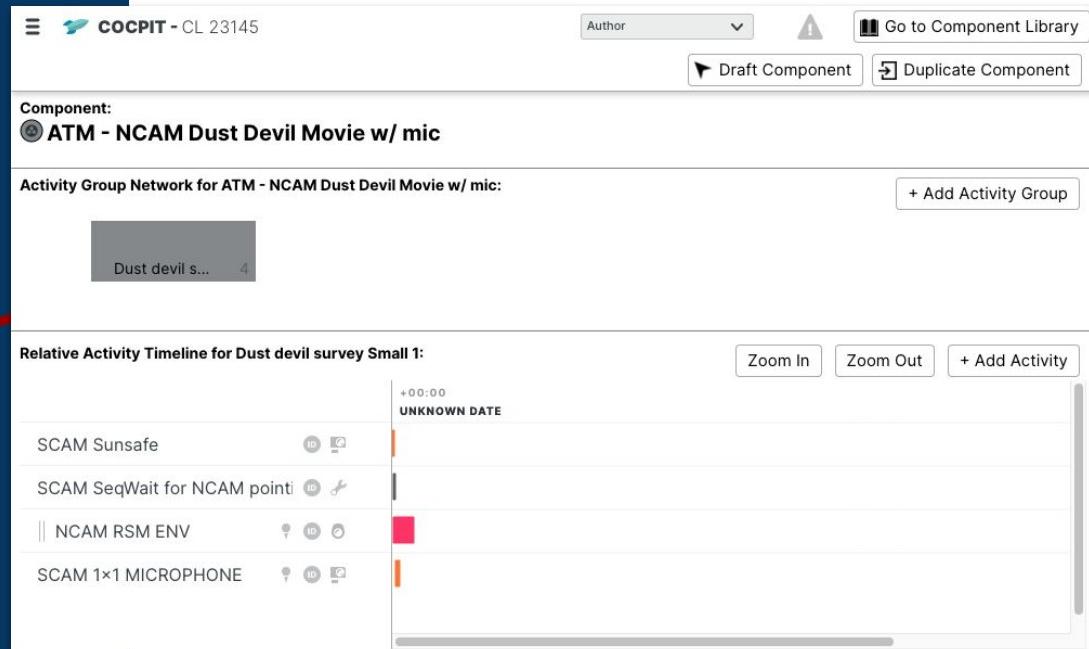
COCPIT Navigator		
Name	Hyperlink	Last Modified
PINNED		
ActID	cocpit_url/navigator/?folder=actid	18:36 May 20, 2021
Component Library	cocpit_url/navigator/?folder=component-library	09:41 Oct 12, 2020
Conjunction	cocpit_url/navigator/?folder=conjunction	11:49 Sep 13, 2021
FTA	cocpit_url/navigator/?folder=fta	23:56 Jun 10, 2021
HGA Heating	cocpit_url/navigator/?folder=hga-heating	04:03 May 21, 2021
LAP	cocpit_url/navigator/?folder=lap	11:32 Feb 10, 2021
Look_Ahead_Plan	cocpit_url?plan=unique_id	08:05 Oct 12, 2021
P6 CL (v1629930542)	cocpit_url/?complib=1629930542	15:58 Oct 01, 2021
SFP/Runout Plan Layouts	cocpit_url/navigator/?folder=anomaly	23:16 Feb 07, 2021
Sol00213_Tactical	cocpit_url/?plan=unique_id	01:16 Oct 12, 2021
Sol00214_Tactical	cocpit_url/?plan=unique_id	11:14 Oct 08, 2021
Sol00216_Tactical	cocpit_url/?plan=unique_id	16:50 Oct 11, 2021
Sol00217_Tactical	cocpit_url/?plan=unique_id	04:41 Oct 08, 2021
Sol00224_Tactical	cocpit_url/?plan=unique_id	19:07 Oct 06, 2021
Sol00231_Tactical	cocpit_url/?plan=unique_id	20:10 Oct 11, 2021
Tactical	cocpit_url/navigator/?folder=tactical	14:43 Jan 13, 2021
workspace	cocpit_url/navigator/?folder=workspace	09:41 Oct 12, 2020

- Companion application
- Management of plans, component libraries and folders
- Supports planning workflows
 - Bookmarking
 - Plan level operations
 - Color tagging
- Query search for metadata and archival information

Component Library

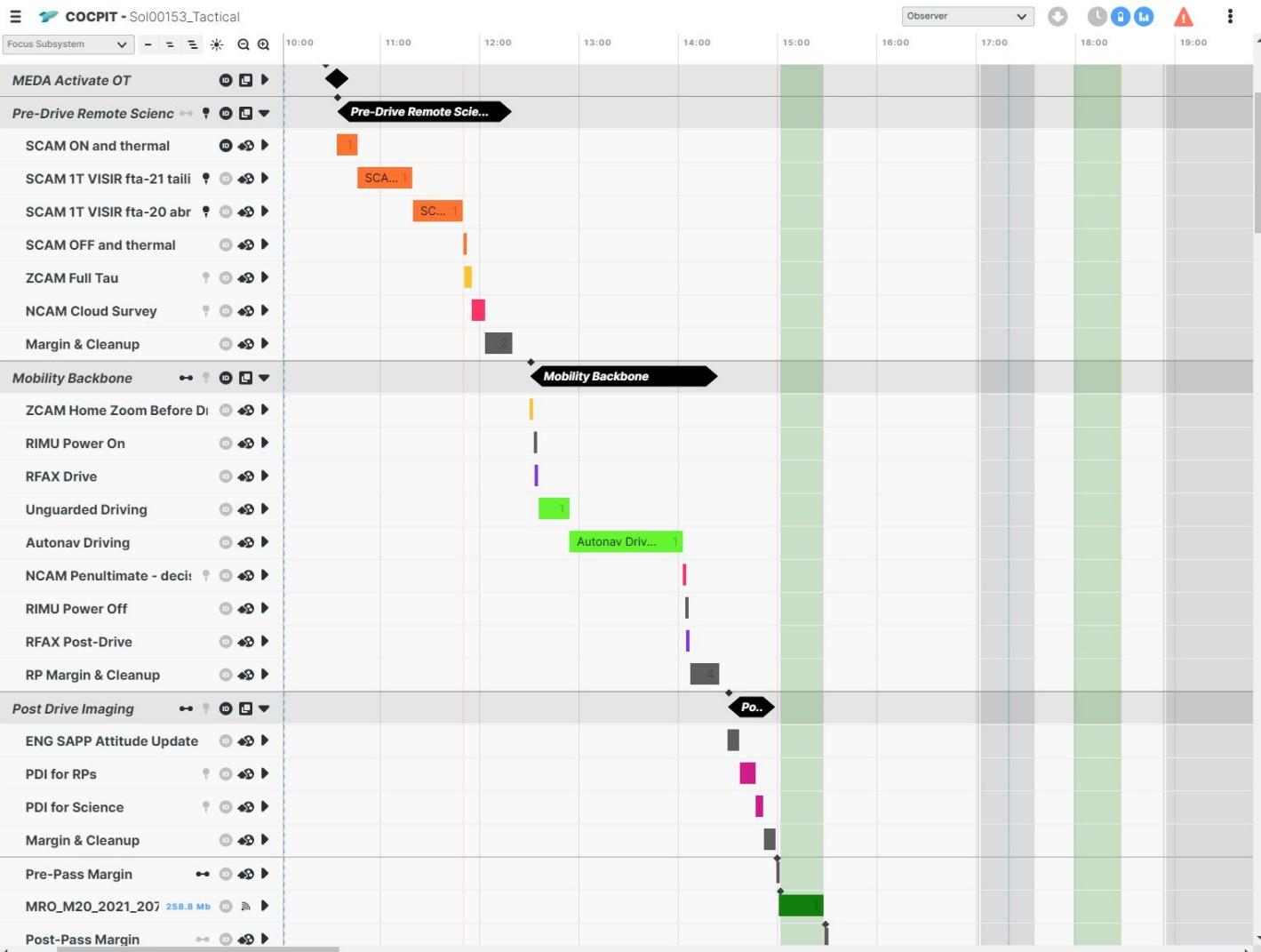
- Collection of reusable components with resource information (energy, data, duration)
- Planning units for Campaign Implementation and Tactical Planning phases

Component Name	Author	Total Energy	Total Data	Critical Data	Duration
ATM - MEDA Background Noon	jbeek	2.5 Whrs	0.0 Mb	0.0 Mb	00:10:51
ATM - MEDA Background Odd Hour	mtrautma	200.8 Whrs	0.0 Mb	0.0 Mb	14:33:12
ATM - MEDA Load OT	jbeek	1.1 Whrs	0.0 Mb	0.0 Mb	00:10:00
ATM - MOXIE	jbeek	857.7 Whrs	34.1 Mb	34.1 Mb	03:45:46
ATM - NCAM Cloud Survey	klichten	7.3 Whrs	24.6 Mb	0.0 Mb	00:08:15
ATM - NCAM Dust Devil Movie - M	mtrautma	3.9 Whrs	25.8 Mb	0.0 Mb	00:11:00
ATM - NCAM Dust Devil Movie - S	mtrautma	3.8 Whrs	25.8 Mb	0.0 Mb	00:10:30
ATM - NCAM Dust Devil Movie Quick	mtrautma	7.3 Whrs	24.6 Mb	0.0 Mb	00:08:15
ATM - NCAM Dust Devil Movie w/ mic	jbeek	6.0 Whrs	92.6 Mb	0.0 Mb	00:11:04
ATM - NCAM Dust Devil Survey	klichten	7.7 Whrs	18.4 Mb	0.0 Mb	00:09:10
ATM - NCAM RSM ENV	mtrautma	7.3 Whrs	24.6 Mb	0.0 Mb	00:08:15

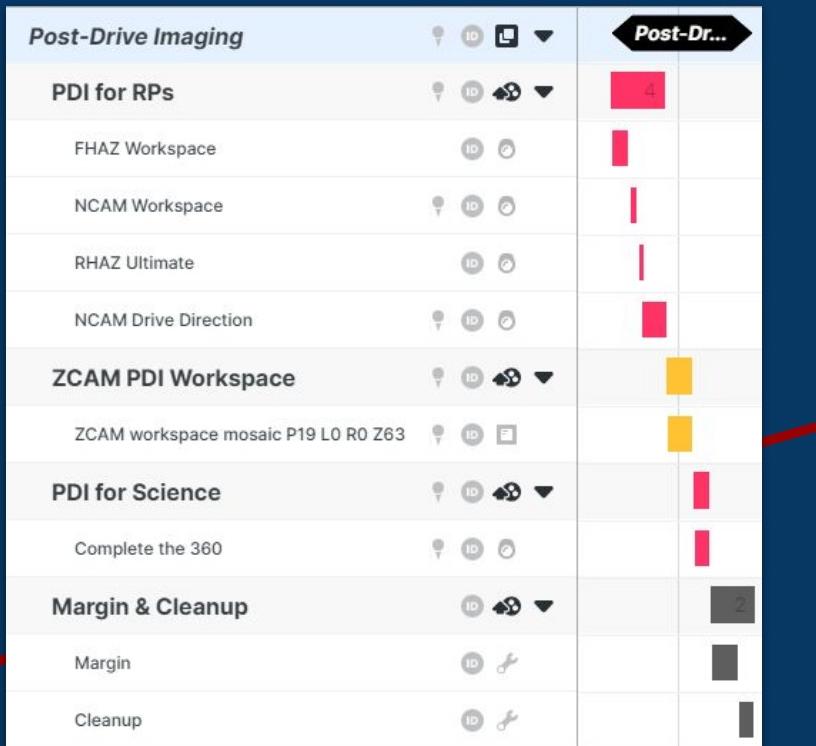


Timeline

- Main view to manipulate and review the plan
- Hierarchical and chronological order
- Row labels have shortcuts to important information
- Vertical Overlays show comm passes and when rover is asleep
- Blue dash lines show handovers
- Time window constraint representation



Plan Structure



- Planning Unit Types
 - Components contain Activity Groups
 - Activity Groups contain Activities
 - Activities are of many different Types
- Components are plan fragments that can be added to and removed from plan
- Timeline shows Activity Groups and Activities as children (not Components)
- During planning, Activity Groups can be grouped into Merge Sets (back rectangle with diamond corners)

Overview

- Alternate view showing Components, Activity Groups and Activity hierarchy
- Column per Sol
- Shows Planning Units outside of the bounds of execution
- Per-Sol Data and Power Resources

Pre Plan

+ Handover Sol 153

Copilot Activity Groups	⌚ ➡	Copy of Copy of Copy of Copy of Copy ⌚ ➡
ATM - MEDA Background Extended	⌚ ➡	Copy of Copy of Copy of Copy of Cop: ⌚ ➡
Sol_0153_AM_HGA_DFE	⌚ ➡	Copy of Copy of Copy of Copy of Copy ⌚ ➡
EO - Uploss Timer	⌚ ➡	IO - SCAM ON/OFF (All) ⌚ ➡ ATM - MEDA Activate OT ⌚ ➡ Copy of UTIL - Placeholder - CPU On ⌚ ➡ UTIL - Margin & Cleanup ⌚ ➡ Margin & Cleanup ⌚ MAO ➡ Margin ⌚ ➡ Cleanup ⌚ ➡ RS - SCAM VISIR Target [Su] ⌚ ➡ ATM - MEDA Background Extended ⌚ ➡ RS - SCAM VISIR Target [Su] ⌚ ➡ UTIL - Geometric Events ⌚ ➡

Sol 153 Resources

Modeled Incoming SOC	96.4%
Override Incoming SOC	%
Modeled Outgoing SOC	83.8%
Minimum Usable SOC	65.6% 16:30:32
Maximum RPAM	19.7 A 11:20:28
Max Battery Load Current	16.8 A 11:24:02
Available Decisional DV	68.5 Mb
Decisional Pass DV	68.5 Mb (MRO_M20_2...)
Decisional Bin Reached	68
Total Acquired DV	2529.6 Mb

Sol 154 Resources

Modeled Incoming SOC	83.7%
Override Incoming SOC	%
Modeled Outgoing SOC	58.6%
Minimum Usable SOC	52.5% 06:08:50
Maximum RPAM	19.8 A 03:00:00
Max Battery Load Current	16.5 A 03:00:00
Available Decisional DV	613.3 Mb
Decisional Pass DV	613.3 Mb (MVN_M20_2...)
Decisional Bin Reached	78
Total Acquired DV	442.2 Mb

Post P

EO - LGA Nominal Beep	⌚ ➡
EO - Engineering Keepout	⌚ ➡
UTIL - Geometric Events	⌚ ➡
ATM - MEDA Background Extended	⌚ ➡
Copy of UTIL - Placeholder - CPU On	⌚ ➡
Copy of ATM - NCAM Dust Devil Sur	⌚ ➡
Copy of ATM - Tau ZCAM Full [Z]	⌚ ➡
IO - SCAM ON/OFF (IR/RMI/MIC)	⌚ ➡
RS - SCAM VISIR Target [Su]	⌚ ➡
Copy of RS - SCAM VISIR Target [Su]	⌚ ➡
Copy of IO - SCAM LIBS Calibration Sin	⌚ ➡
Copy of IO - SCAM LIBS Calibration Sin	⌚ ➡
Copy of UTIL - Margin & Cleanup	⌚ ➡
UTIL - Placeholder - CPU On	⌚ ➡

Details Panel

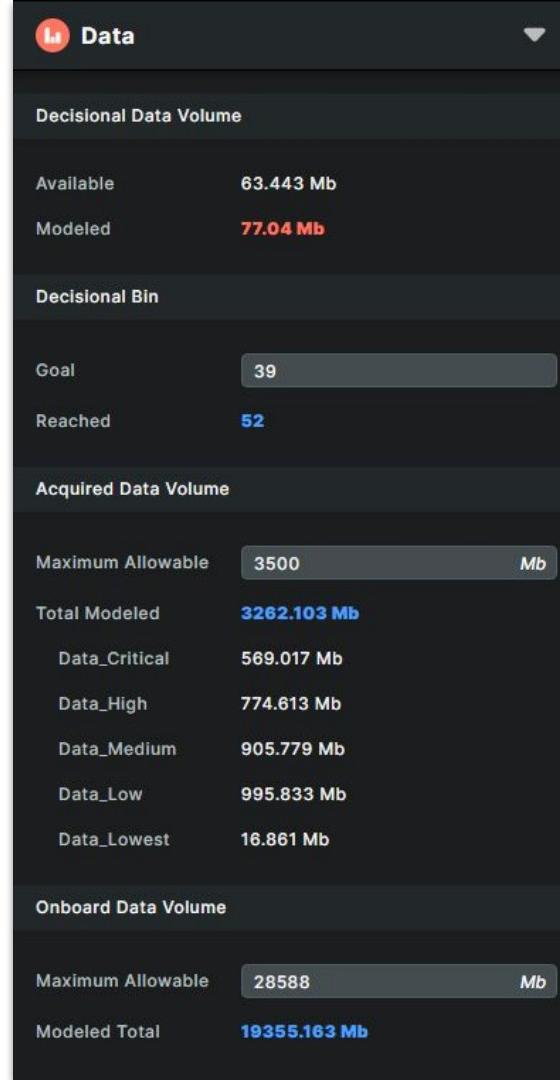
- Selection-aware panel for editing
- Each planning unit type shows the relevant sections, operations and parameters for its type
- Respect permissions by role and type of planning unit
- Multiselect shows metrics and supported operations for selection
- Same details panel available in all COCPIT views

The screenshot displays the COCPIT Details Panel for a selected planning unit, specifically MEDA Session 15. The panel is divided into several sections:

- Activity Group:** Shows basic activity details: Total Duration (02:14:57), Start Time (Sat 153 13:00:00), Gap (00:55:40), and Span (03:10:37). It also lists "Selected (2)" items: MEDA Session 13 and MEDA Session 15.
- Constraints:** A section for defining operational constraints. It includes fields for "Pin" (Start: Sol 153, 15:00:00) and "Window" (Start: Sol, End: Sol). There is also a "Dependency" section with a plus sign icon.
- Resource Effects:** A section showing energy consumption: Total Energy (8.0 Whrs).
- Parameters:** A section for setting parameters. It includes "Show Expert Parameters" (unchecked), "Seq_ID" (Seq_ID), "Mandatory" (checked), "Mstr_Seq_Activate" (unchecked), "Arm_Heating" (Default dropdown), and "Bit_Carousel_Heati..." (Default dropdown).
- Multi Select:** A sidebar showing metrics and operations for the selected items: MEDA Session 13 and MEDA Session 15. It includes buttons for "WATERFALL", "COMPRESS RIGHT", "DEPENDENCY", "MERGE", "COPY", and "DELETE".
- Current Constraints:** A section showing the current constraints for the selected items.

Data Modeling

- COCPIT models data generated, reprioritized, retransmitted and downlinked by rover
- Activity parameters contribute to the calculation of data (using formulas in AD)
- Crucial to understand when the data will be available for analysis Earth
 - Decisional Data is data needed for next tactical planning cycle
- Activities show data contributions
- Data Resource Panel shows aggregated values per criticality at the plan-level and a specific time in the plan



Collaboration & Interfaces

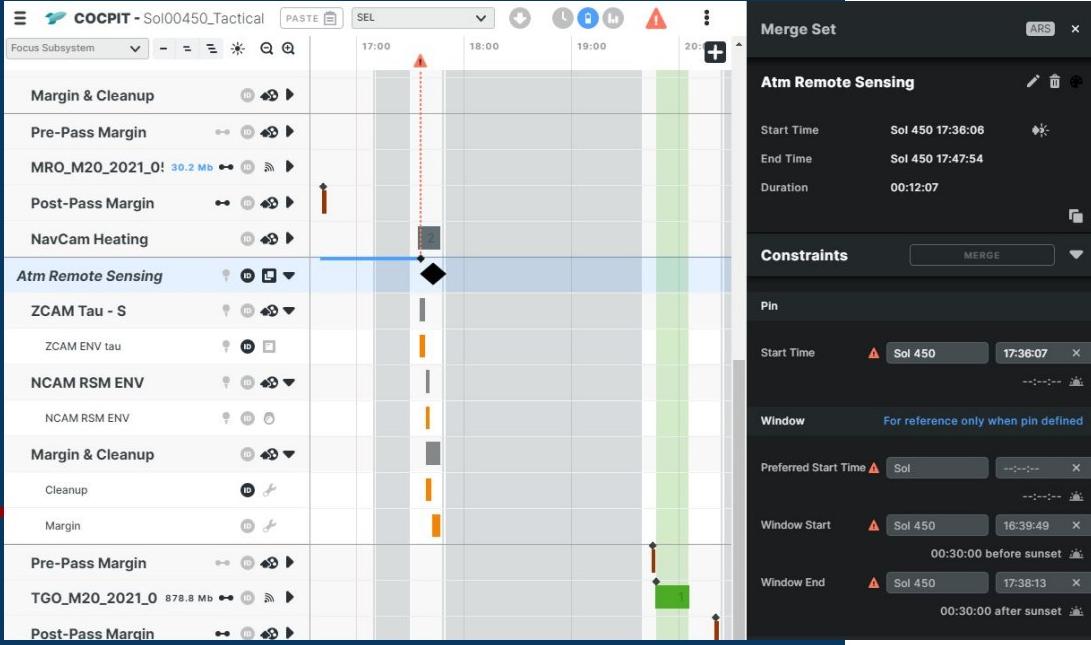
Collaboration

- Team Members around the world can access the live plan with a web browser
 - Changes are distributed to all clients automatically to keep them up to date
- Role-based permissions control actions

Interfaces

- COCPIT's Application Programming Interfaces (APIs) allow other tools to submit changes programmatically
- A pub/sub service sends notifications to tools that are interested in receiving plan changes
- Plan Patch allows Rover Planners to optimize rover motions by adding, removing and reordering activities with a bulk change operation

Temporal Constraint Network



Constraint Types

- Pin to start at a specific time
- Execution Window
 - Earliest Start, Latest End, Preferred Start
- Dependency
 - Start before or after another planning unit

COCPIT uses a Temporal Constraint Network to evaluate the set of constraints in the plan and warns users if they are inconsistent or circular.

Autonomous Scheduling

Planning vs. Scheduling

- COCPIT users are responsible for planning: selecting desired activities, setting parameters and constraints
- An autonomous scheduler determines actual start times for each planning unit

Scheduling Considerations

- Predicted duration
- Timing and dependency constraints
- Data volume and power limits
- Mechanical state requirements and effects
- Allowable parallelism

On the ground and on-board

- Ground software Copilot is heavily integrated with COCPIT
- Perseverance flight software will also support autonomous scheduling
- Both are informed by data in the COCPIT plan

Sequencing

- After plan is finalized, it is used to generate the sequences that run on the rover.
- Individual activities are converted to sequences. Activity parameters determine which commands and arguments are generated.
- The structure of the plan is used to build master and submaster sequences that coordinate the flow of execution of other sequences.
 - Timing constraints map to commands to pause until a given time.
 - Merge Sets and Groups map to submaster sequences.
 - Wake and Sleep activities map to commands instructing the spacecraft when to wake up and shut down.

Summary

Thank you to the COCPIT management, design, test, infrastructure, and development team for working tirelessly to make this software successful. Anthony Robertson, Ryan Goetz, Kathryn Yu, Roxana Gonzalez Burgos, Joshua Camacho, Jimin Zheng, Sara Schnadt, Adrian Galvin, Basak Alper Ramaswamy, Guy Pyrzak, Hoan Luu, Natalie Rezek, Jon Blossom and Usha Guduri.

As missions become more complex, tools must allow more integration, automation and collaboration to enable less work hours for operators and more science on Mars.

COCPIT and Playbook are modern planning and scheduling tools paving the way for software supporting humans and robotic exploration of Moon, Mars and beyond.

